APPLICATION

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TITLE: NOISE REMOVAL CIRCUIT AND METHOD

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NOISE REMOVAL CIRCUIT AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority upon
Japanese Patent Application No. 2002-349363 filed on
December 2, 2002, which is herein incorporated by
reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a noise removal
circuit and a noise removal method.

2. Description of the Related Art

Prior art related to signal noise removal are
covered in signal recording and reproduction devices
such as a hard disk and an optical disk. For instance,
optical disks that allow data recording using laser beam
are classified into write-once optical disks such as
CD-R, DVD-R and DVD+R and rewritable optical disks such
as CD-RW, MD, DVD-RAM, DVD-RW, DVD+RW and MO.

A recording and reproduction device for such
optical disks (hereinafter written as an "optical disk
device") comprises, as an example, an optical pickup,
a WBL (wobble signal) detection unit, an LPP detection
unit, a write clock generation unit, a decoder, a
spindle motor, a spindle servo circuit, an optical
pickup servo circuit, a processor, an interface unit,

an encoder, a laser control unit and a ROM.

Of all the components, the aforementioned WBL signal extraction circuit is shown in Fig. 11. An optical pickup 11 irradiates an optical beam onto the
5   recording track of an optical disk 1 based on a laser control signal. A WBL detection unit 12 comprises a wobble (WBL) signal B.P.F. (Band Pass Filter) circuit 12a, a comparator 12b and so on. A radial push-pull signal SDT, detected based on a reflected light of an
10   optical beam B, is input to the wobble signal B.P.F. circuit 12a. The wobble signal B.P.F. circuit 12a removes a high-frequency noise component and extracts a WBL signal component A_WBL from the radial push-pull signal SDT (See, e.g., Japanese Patent Application
15   Laid-open Publication No. 2000-293855).

A binary-valued WBL signal is output by comparing the WBL signal component A_WBL (negative side) and a reference voltage (positive side) using the comparator 12b. The binary-valued WBL signal is output to the
20   write clock generation unit, the spindle servo circuit 17 and so on.

In extracting the WBL signal component A_WBL, the wobble signal B.P.F. circuit 12a removes the high-frequency noise component from the radial
25   push-pull signal SDT. Nevertheless, some noise component has remained in the WBL signal component A_WBL after passage through the wobble signal B.P.F. circuit

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12a.

Jitter occurs in the clock during optical disk recording or reproduction in the event of an increase in this noise component. Occurrence of the jitter has

5 hindered synchronization of the optical disk rotation speed and the clock, resulting in recording or reproduction failure and other problems.

The wobble signal may become amplitude-modulated depending on the disk or pickup condition, occasionally

10 resulting in the wobble signal being impossible to read correctly.

Further, the wobble signal may be lost as a result of disk damage or other cause, occasionally adversely affecting the control system using the wobble signal.

15 Still further, an AC signal may be superposed onto the wobble signal at disk rotation cycles due to effects such as unevenness or double refraction in disk protective film and pickup condition, occasionally resulting in the wobble signal being difficult to read

20 correctly.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a noise removal circuit and method capable

25 of overcoming the above deficiencies.

In order to achieve the above and other objects, according to a first aspect of the present invention

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there is provided a noise removal circuit comprising a 180-degree odd multiple shifting section for outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple

5   of 180 degrees and difference output section for outputting a difference between the input signal and the 180-degree shifted signal.

According to a second aspect of the present invention there is provided a noise removal circuit

10 comprising a 360-degree shifting section for outputting a 360-degree shifted signal that is phase-shifted from an input signal by an integral multiple of 360 degrees and a sum output section for outputting a sum of the input signal and the 360-degree shifted signal.

15 According to a third aspect of the present invention there is provided a noise removal circuit comprising a 180-degree odd multiple shifting section for outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple

20 of 180 degrees, a 360-degree shifting section for outputting a 360-degree shifted signal that is phase-shifted from an input signal by an integral multiple of 360 degrees and calculation output section for outputting calculation results of a difference

25 between the input signal and the 180-degree shifted signal and a sum of the input signal and the 360-degree shifted signal.

According to a fourth aspect of the present invention there is provided a noise removal method comprising outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple

5   of 180 degrees and outputting a difference between the input signal and the 180-degree shifted signal.

According to a fifth aspect of the present invention there is provided a noise removal method comprising outputting a 360-degree shifted signal that

10   is phase-shifted from an input signal by an integral multiple of 360 degrees and outputting a sum of the input signal and the 360-degree shifted signal.

According to a sixth aspect of the present invention there is provided a noise removal method

15   comprising outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple of 180 degrees, outputting a 360-degree shifted signal that is phase-shifted from the input signal by an integral multiple of 360 degrees and outputting

20   calculation results of a difference between the input signal and the 180-degree shifted signal and a sum of the input signal and the 360-degree shifted signal.

BRIEF DESCRIPTION OF THE DRAWINGS

25   The above and other objects, aspects, features and advantages of the present invention will become more apparent from the following detailed description when

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taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram showing the principle of noise removal according to a first embodiment of the

5 present invention;

Fig. 2 is a specific circuit diagram of a phase shifting circuit shown in Fig. 1 according to the first embodiment of the present invention;

Fig. 3 is a circuit diagram of a noise removal

10 circuit according to the first variant of the first embodiment of the present invention;

Fig. 4 is a specific circuit diagram of a frequency-controlled phase shifting circuit shown in Fig. 3 according to the first variant of the first

15 embodiment of the present invention;

Fig. 5 is a specific circuit diagram of a phase comparator shown in Fig. 3 according to the first variant of the first embodiment of the present invention;

20 Fig. 6 is a circuit diagram of a noise removal circuit according to the second variant of the present invention;

Fig. 7 is a circuit diagram of a VCO circuit according to an embodiment of the present invention;

25 Fig. 8 is a block diagram showing the principle of noise removal according to a second embodiment of the present invention;

Fig. 9 is a circuit diagram of a noise removal circuit according to the second embodiment of the present invention;

Fig. 10 is a block diagram showing the principle of noise removal according to a third embodiment of the present invention; and

Fig. 11 is a functional block diagram focusing on a WBL detection unit 12 and an LPP detection unit 13 in an optical disk recording-reproduction device.

DETAILED DESCRIPTION OF THE INVENTION

At least the following items will become apparent from descriptions of this specification and of the accompanying drawings.

A first aspect of the present invention there is provided a noise removal circuit comprising a 180-degree odd multiple shifting section for outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple of 180 degrees and difference output section for outputting a difference between the input signal and the 180-degree shifted signal. This ensures effective reduction of noise component in the input signal.

According to a second aspect of the present invention there is provided a noise removal circuit comprising a 360-degree shifting section for outputting a 360-degree shifted signal that is phase-shifted from

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an input signal by an integral multiple of 360 degrees and a sum output section for outputting a sum of the input signal and the 360-degree shifted signal.

This ensures effective reduction of noise
5   component in the input signal.

According to a third aspect of the present invention there is provided a noise removal circuit comprising a 180-degree odd multiple shifting section for outputting a 180-degree shifted signal that is
10   phase-shifted from an input signal by an odd multiple of 180 degrees, a 360-degree shifting section for outputting a 360-degree shifted signal that is phase-shifted from an input signal by an integral multiple of 360 degrees and calculation output section
15   for outputting calculation results of a difference between the input signal and the 180-degree shifted signal and a sum of the input signal and the 360-degree shifted signal. This provides more efficient noise removal effects by calculating the results of the
20   difference between the input signal and the 180-degree shifted signal and the sum of the input signal and the 360-degree shifted signal.

The noise removal circuit may further comprise a synchronizing signal output section for outputting a
25   synchronizing signal for synchronizing the input signal and the 180-degree shifted signal, in which the difference output section output the difference in

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response to the synchronizing signal. This ensures synchronization between the input signal and the 180-degree shifted signal using the synchronizing signal output section, thus allowing more precise phase

5   shifting operation.

The noise removal circuit may further comprise a synchronizing signal output section for outputting a synchronizing signal for synchronizing the input signal and the 360-degree shifted signal, in which the sum

10   output section output the sum in response to the synchronizing signal. This ensures synchronization between the input signal and the 360-degree shifted signal using the synchronizing signal output section, thus allowing more precise phase shifting operation.

15   The synchronizing signal output section may be constituted by a phase-locked loop circuit and generate the synchronizing signal based on the input signal. This ensures synchronization between the input signal and the shifted signal using the phase-locked loop

20   circuit, thus allowing more precise phase shifting operation.

The synchronizing signal output section may be constituted by a delay-locked loop circuit and generate the synchronizing signal based on the input signal.

25   This ensures synchronization between the input signal and the shifted signal using the delay-locked loop circuit, thus allowing more precise phase shifting

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operation. This also ensures faster phase adjustment as compared with the phase-locked loop circuit that pulls in frequency.

The input signal may be a wobble signal for
5   rotation control detected from optical disk's recording track. This reduces noise component in the wobble signal, preventing occurrence of jitter during optical disk recording and reproduction. As a result, problems derived from noise in the wobble signal can be resolved
10   such as failure to achieve synchronization between optical disk rotation speed and clock, thus allowing proper recording and reproduction.

In order to attain the above and other objects, according to a fourth aspect of the present invention
15   there is provided a noise removal method comprising outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple of 180 degrees and outputting a difference between the input signal and the 180-degree shifted signal. This
20   ensures effective reduction of noise component in the input signal.

According to a fifth aspect of the present invention there is provided a noise removal method comprising outputting a 360-degree shifted signal that
25   is phase-shifted from an input signal by an integral multiple of 360 degrees and outputting a sum of the input signal and the 360-degree shifted signal. This ensures

effective reduction of noise component in the input signal.

　　　According to a sixth aspect of the present invention there is provided a noise removal method
5　comprising outputting a 180-degree shifted signal that is phase-shifted from an input signal by an odd multiple of 180 degrees, outputting a 360-degree shifted signal that is phase-shifted from the input signal by an integral multiple of 360 degrees and outputting
10　calculation results of a difference between the input signal and the 180-degree shifted signal and a sum of the input signal and the 360-degree shifted signal. This provides more efficient noise removal effects by calculating the results of the difference between the
15　input signal and the 180-degree shifted signal and the sum of the input signal and the 360-degree shifted signal.

　　　The input signal may be a wobble signal for rotation control detected from optical disk's recording
20　track. This reduces noise component in the wobble signal, preventing occurrence of jitter during optical disk recording and reproduction. As a result, problems derived from noise in the wobble signal can be resolved such as failure to achieve synchronization between
25　optical disk rotation speed and clock, thus allowing proper recording and reproduction.

<First Embodiment>

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A first embodiment will now be described with reference to Figs. 1 to 7. First, a (2n-1)*180-degree phase shifting circuit (180-degree odd multiple shifting section) 100 generates a signal phase-shifted

5   by (2n-1)*180 degrees from a signal component of an input signal I (hereinafter referred to as "180-degree shifted signal") and outputs the signal to the non-inverted input terminal (+) of an operational amplifier OP10, as shown in the block diagram of Fig.

10   1 showing the principle of noise removal. It should be noted that "n" is an integer. It should be also noted that the input signal I is input to the inverted input terminal (-) of the operational amplifier (difference output section) OP10.

15   Therefore, an output O of the operational amplifier OP10 is a difference between the input signal I and the 180-degree shifted signal. The noise removal circuit for the input signal I is thus configured.

        The principle of noise removal from the input

20   signal I will be described using mathematical formulas.

        If we let a pure wobble signal be $WO=A*\sin(\omega t)$ and a noise component be $N(t)$, then an input signal $I(t)$ can be expressed by $I(t)=A*\sin(\omega t)+N(t)$. In the principle of noise removal of this embodiment, a

25   difference is taken between the input signal $I(t)$ and a signal phase-shifted from the input signal by (2n-1)*180 degrees (n is an integer).

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That is, the signal phase-shifted by (2n-1)*180 degrees (n is an integer) from the input signal component or I(t-(2n-1)*π) is expressed by A*sin(ωt-(2n-1)*π)+N(t). Therefore, taking the

5   difference between the input signal I(t) and the signal phase-shifted by (2n-1)*180 degrees from the signal component of the input signal, the resultant signal can be expressed by

I(t)-I(t-(2n-1)*π)=A*(sin(ωt)-sin(ωt-(2n-1)*π))

10   +√(2*N(t)^2)=2*A*sin(ωt)+ √2*N(t).

That is, although the S/N ratio of the input signal I(t) is originally A/N(t), the S/N ratio after noise removal is √2*A/N(t), providing a √2 fold improvement in S/N ratio.

15   Specific circuits implementing the noise removal operation expressed by these mathematical formulas will be described with reference to Figs. 2 to 7. Fig. 2 shows a specific circuit configuration of the phase shifting circuit shown in Fig. 1. The input signal I(t)

20   is input to the inverted input terminal (-) of an operational amplifier OP1 via a resistor R1, capacitors C1 and C2 and a resistor R3. The non-inverted input terminal (+) of the operational amplifier OP1 is grounded. The output of the operational amplifier OP1

25   is fed back to the inverted input terminal (-) of the operational amplifier OP1 via the capacitors C1 and C2 and the resistor R3. Additionally, the output of a

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resistor R4 connected to the output terminal of the operational amplifier OP1 is fed back to the terminal on the signal input side of the resistor R1 via the resistor R2.

5   The output of the operational amplifier OP1 is output via the resistor R4 and a buffer BUF1. The output signal of the buffer BUF1 is a signal phase-shifted by $(2n-1)*180$ degrees from the signal component of the input signal input to the resistor R1.

10   <First Variant of First Embodiment>

The first variant of the first embodiment shown in Fig. 1 will be described with reference to Fig. 3. In this variant, a DLL (delay-locked loop)-based phase-adjusting circuit is employed as the noise

15   removal circuit shown in Fig. 1 to achieve synchronization with the input signal I. That is, a frequency-controlled circuit is used as the phase shifting circuit, and the output of the phase shifting circuit is inverted by an inverter and input to one of

20   the input terminals (an input 2) of a phase comparator (synchronizing signal output section). The input signal I is input to the other input terminal (an input 1) of the phase comparator. The output of the phase comparator is input to the frequency-controlled phase

25   shifting circuit as a frequency control signal that serves as a synchronizing signal. It should be noted that high-frequency noise in the phase comparator

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output is removed by a capacitor C0.

The phase comparator can synchronize the input signal and the 180-degree shifted signal, thus allowing more precise phase shifting operation.

5   Use of a DLL-based phase-adjusting circuit ensures faster phase adjustment as compared with the PLL discussed later that pulls in frequency.

Fig. 4 shows a specific circuit configuration of the frequency-controlled phase shifting circuit shown

10   in Fig. 3. The capacitors C1 and C2 in the phase shifting circuit of Fig. 2 discussed earlier are replaced by variable capacitors VC1 and VC2, with the capacitances of the variable capacitors VC1 and VC2 changed by a frequency control signal. Variation of

15   the capacitances produces a signal phase-shifted from the input signal by $(2n-1)*180$ degrees.

Next, Fig. 5 shows a specific circuit configuration of the phase comparator shown in Fig. 3. The phase comparator is configured by combining two

20   groups of circuits, each made up of a D-type flip-flop (abbreviated as "D-FF"), an inverter and a constant current source. More specifically, the phase comparator outputs the frequency control signal in response to two inputs 1 and 2. The input 1 is input

25   to a clock terminal C of a D-FF 1 and a reset terminal R of a D-FF 2. An output Q of the D-FF 1 is supplied to a switch 1 as an on-off signal and to a data terminal

D of the D-FF 2 via an inverter 1. The other input 2

is input to a clock terminal C of the D-FF 2 and a reset

terminal R of the D-FF 1. An output Q of the D-FF 2

is supplied to a switch 2 as an on-off signal and to

5   a data terminal D of the D-FF 1 via an inverter 2.

The   phase   comparator   thus   configured

complementarily turns switches SW1 and SW2 on or off.

This allows the outputs Q of the D-FF 1 and the D-FF

2 to be alternately output to the shifting circuit as

10   a frequency control signal.

<Second Variant of First Embodiment>

The second variant of the first embodiment shown

in Fig. 1 will be described with reference to Fig. 6.

In the second variant, a PLL (phase-locked loop)-based

15   phase-adjusting circuit is employed as the noise

removal circuit shown in Fig. 1 to achieve

synchronization with the input signal I. That is, a

VCO circuit (synchronizing signal output section) is

added to the first variant of Fig. 3 discussed earlier.

20   The second variant will be described, focusing on the

differences from the first variant shown in Fig. 3. The

output of the phase comparator (synchronizing signal

output section) shown in Fig. 5 is input to the

frequency-controlled phase shifting circuit shown in

25   Fig. 4 and to the VCO circuit as a frequency control

signal that serves as a synchronizing signal. The

output of the VCO circuit is fed back and input to the

phase comparator (input 2). It should be noted that high-frequency noise in the phase comparator output is removed by the capacitor C0.

The PLL circuit including the phase comparator
5 ensures synchronization between the input signal and the 180-degree shifted signal, thus allowing more precise phase shifting operation.

In the noise removal circuit of this embodiment, if the frequency-controlled phase shifting circuit and
10 the VCO circuit are packed on the same chip, there is a correlation in center frequency between the two circuits, thus allowing more precise phase control.

Fig. 7 shows a specific circuit configuration of the VCO circuit. The output of an operational
15 amplifier OP70 is inverted by an inverter. The inverted output of the inverter is input to the phase comparator shown in Fig. 6 as the output of the VCO circuit. The inverted output of the inverter is fed back to the inverted input terminal (-) of the
20 operational amplifier OP70 via a resistor R70, variable capacitors VC71 and VC71 and a resistor R71. Additionally, the output of the operational amplifier OP70 is fed back to the inverted input terminal (-) of the operational amplifier OP70 via the variable
25 capacitors VC70 and VC71 and the resistor R71. The non-inverted input terminal (+) of the operational amplifier OP70 is grounded.

The capacitances of the variable capacitors VC70 and VC71 are changed by a frequency control signal. Variation of the capacitances changes the VCO circuit output.

5 <Second Embodiment>

The second embodiment will be described with reference to Figs. 8 and 9. First, a signal phase-shifted from the signal component of the input signal I by n*360 degrees (hereinafter referred to as a "360-degree shifted signal") is generated by a 10 n*360-degree phase shifting circuit (360-degree shifting section) 200 and output to one of the non-inverted input terminals (+) of an operational amplifier (sum output section) OP20, as shown in the 15 block diagram of Fig. 8 showing the principle of noise removal. It should be noted that "n" is an integer. The input signal I is input to the other non-inverted input terminal (+) of the operational amplifier OP20. Therefore, an output O of the operational amplifier OP20 20 is the sum of the input signal I and the 360-degree shifted signal. The noise removal circuit for the input signal I is thus configured.

Fig. 9 shows a specific circuit configuration of the phase shifting circuit shown in Fig. 8. That is, 25 a stage consisting of an operational amplifier OP2 and a resistor R5 is further provided in Fig. 9 in place of the buffer BUF1 in the circuit of Fig. 2 showing the

first embodiment. Description of the commonalities between the circuits in Figs. 9 and 2 is as given in the first embodiment. The difference from the circuit shown in Fig. 2 is that the output of the operational

5 amplifier OP1 is input to the inverted input terminal (-) of the operational amplifier OP2 via the resistor R4. The non-inverted input terminal (+) of the operational amplifier OP2 is grounded. The output of the operational amplifier OP2 is fed back to the

10 inverted input terminal (-) of the operational amplifier OP2 via the resistor R5. The output of the operational amplifier OP2 is a signal phase-shifted by n*360 degrees from the signal component of the input signal I input to the resistor R2.

15 In this embodiment, a modification can be made using a DLL-based phase adjusting circuit or PLL-based phase comparing circuit by providing a phase comparator and VCO circuit as with the first embodiment in Figs. 3 and 6.

20 The principle of noise removal from the input signal I will be described using mathematical formulas.

If we let the pure wobble signal be WO=A*sin(ωt) and the noise component be N(t), then the input signal I(t) can be expressed by I(t)=A*sin(ωt)+N(t). In the

25 principle of noise removal of this embodiment, a sum is taken by adding the input signal I(t) and a signal phase-shifted from the input signal by n*360 degrees

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(n is an integer).

That is, the signal phase-shifted from the input signal by n*360 degrees (n is integer) or $I(t-2n\pi)$ is expressed by $A*\sin(\omega t-2n\pi)+N(t)$. Therefore, taking
5   the sum of the input signal $I(t)$ and the signal phase-shifted by n*360 degrees (n is an integer) from the signal component of the input signal, the resultant signal can be expressed by

$$I(t)+I(t-2n\pi)=A*(\sin(\omega t)+\sin(\omega t-2n\pi))$$
10    $$+\sqrt{(2*N(t)^2)}=2*A*\sin(\omega t)+\sqrt{2}*N(t).$$

That is, although the S/N ratio of the input signal $I(t)$ is originally $A/N(t)$, the S/N ratio after noise removal is $\sqrt{2}*A/N(t)$, providing a $\sqrt{2}$ fold improvement in S/N ratio.

15   <Third Embodiment>

The third embodiment will be described with reference to Fig. 10. This embodiment is, as shown in Fig. 10 showing the principle of noise removal, the result of combination of the first embodiment shown in
20   Figs. 1 to 7 and the second embodiment shown in Figs. 8 and 9. The combination produces a synergetic effect.

That is, the (2n-1)*180-degree phase shifting circuit 100 generates a signal phase-shifted by (2n-1)*180 degrees from the signal component of the
25   input signal I (hereinafter referred to as "180-degree shifted signal") and outputs the signal to the inverted input terminal (-) of an operational amplifier

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(calculation output section) OP30. It should be noted that "n" is an integer.

Further, a signal phase-shifted from the signal component of the input signal I by n*360 degrees
5 (hereinafter referred to as "360-degree shifted signal") is generated by the n*360-degree phase shifting circuit 200 and output to the non-inverted input terminal (+) of the operational amplifier OP30. It should be noted that "n" is an integer. The input
10 signal I is input to the non-inverted input terminal (+) of the operational amplifier OP30.

Therefore, an output O of the operational amplifier OP30 is the result of addition of the 360-degree shifted signal and the input signal I and
15 subtraction of the 180-degree shifted signal. The noise removal circuit for the input signal I is thus configured.

The operational amplifier OP30 is constituted by an operational amplifier having three known inputs.
20 The operational amplifier OP30 may be constituted by two stages of two-input operational amplifiers That is, the operational amplifier OP30 is constituted by a first two-input operational amplifier equipped with a non-inverted input terminal (+) and an inverted input
25 terminal (-) and a second two-input operational amplifier equipped with two non-inverted input terminals (+). That is, the output of the first

two-input operational amplifier and the input signal

I are the inputs to the second two-input operational

amplifier   The   output   of   the   second   two-input

operational amplifier is the output O of the operational

5   amplifier OP30.

The principle of noise removal from the input

signal I will be described using mathematical formulas.

Taking the sum of the input signal and the signal

phase-shifted from signal component of the input signal

10   I by n*360 degrees and further taking the difference

from the signal phase-shifted from the signal component

of the input signal by (2n-1)*180 degrees (n is an

integer), the resultant signal can be expressed by

$I(t)+I(t-2n\pi)-I(t-(2n-1)*\pi)=A*(\sin(\omega t)+\sin(\omega t-2n\pi)-$

15   $\sin(\omega t-2n\pi)-\sin(\omega t-(2n-1)*\pi))$

$+\sqrt{(3*N(t)^2)} =3*A*\sin(\omega t)+ \sqrt{3}*N(t)$.

That is, although the S/N ratio of the input signal

I(t) is originally A/N(t), the S/N ratio after noise

removal is $\sqrt{3}*A/N(t)$, providing a $\sqrt{3}$ fold improvement

20   in S/N ratio. The $\sqrt{3}$ fold improvement in S/N ratio in

this embodiment surpasses the improvement achieved in

the first and second embodiments.

<Use of Wobble Signal for Noise Removal>

Wobble signal is used in the noise removal circuits

25   of the first to third embodiments as an applied example

of the present invention. That is, the input signal

to the noise removal circuits of Figs. 1 to 10 is a wobble

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signal for rotation control detected from optical disk's recording track. That is, the input signal to the noise removal circuit is the WBL signal component A_WBL output from the wobble signal B.P.F. circuit 12a

5   in Fig. 11 described in the paragraph touching on the related art. The noise-free output signal from the noise removal circuit is input to the inverted input terminal (-) of the comparator 12b.

Therefore, reduction in noise component in the

10   wobble signal prevents occurrence of jitter during optical disk recording and reproduction. As a result, problems derived from noise in the wobble signal can be resolved such as failure to achieve synchronization between optical disk rotation speed and clock, thus

15   allowing proper recording and reproduction.

Even if the wobble signal is amplitude-modulated depending on the disk or pickup condition, phase-shifting of the signal as well as taking the sum and/or difference ensures averaging of the amplitude

20   modulation, thus allowing correct reading of the wobble signal.

Further, even if the wobble signal is lost, phase-shifting of the signal as well as taking the sum or difference ensures interpolation of the lost wobble

25   signal, thus avoiding adverse effect on the control system using the wobble signal.

Still further, even if an AC signal is superposed

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onto the wobble signal at disk rotation cycles, the
noise removal circuit performs phase shifting by
(2n-1)*180 degrees and takes the difference from the
signal at the immediately previous moment, rejecting
5   a DC offset and AC signal at disk rotation cycles and
thereby allowing correct reading of the wobble signal.

While the present invention was described based
on specific embodiments, the present invention is not
limited thereto, but is capable of variation and
10   modification without departing from the spirit and
scope of the invention.

The S/N ratio of wobble and other signals can be
improved.